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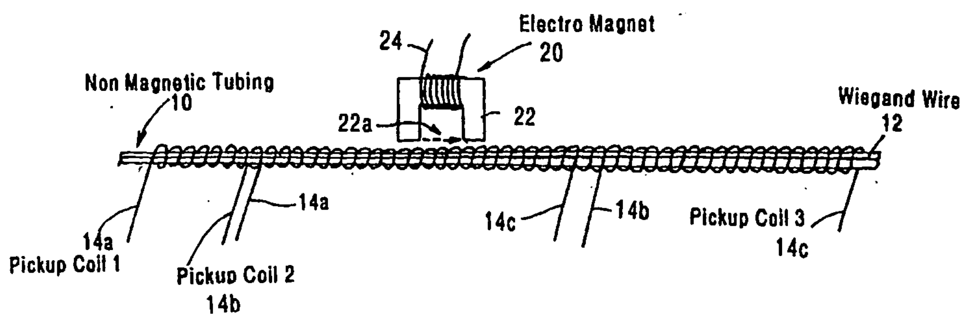

(57) Abstract

A linear position sensor that utilizes the "Wiegand Effect" to sense the position of an object along a linear path of travel. A magnetic field generator such as an electro magnet generates an alternating magnetic field and is movable relative to a linear path of travel. A Wiegand wire extends along and is adjacent to that linear path of travel so that a segment of Wiegand wire located within the alternating magnetic field changes its magnetic state in response thereto. Pickup coils are wound on different portions of the Wiegand wire and a pulse is produced on the respective pickup coil that is wound on that segment of Wiegand wire changing magnetic states. The position of the magnetic field generator along the linear path is ascertained from the pickup coil having pulses thereon.

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WIEGAND EFFECT LINEAR POSITION SENSOR

BACKGROUND OF THE INVENTION

This invention relates to positional sensors and is particularly directed to a linear positional sensor that utilizes the "Wiegand Effect" to sense the position of an object along a linear path of travel.

Known linear position sensors are used in various devices and in various industries. For example, linear position sensors are currently utilized in vehicle occupant restraint systems to ascertain the position of vehicle seats in automobiles. Generally, a linear position sensor provides a position signal indicative of the position of the vehicle seat thus identifying the position of the vehicle occupant. The position signal is utilized with various other information including automobile speed and acceleration\deceleration to control the various safety features of the automobile such as when to deploy an air bag as well as the amount of force of the deployment.

While there has been considerable advancement in systems that utilize position information, there still is a need to improve these devices and thus there is a need for an improved positional sensor.

It is therefore an object of this invention to provide an improved linear position sensor for use in various devices and systems that require position information.

It is another object of this invention to provide an improved linear position sensor with various advantages and features, as discussed below, that are not provided within existing linear position systems.

Various other objects, advantages and features of the present invention will become readily apparent to those of ordinary skill in the art, and the novel features will be particularly pointed out in the appended claims.

SUMMARY OF THE INVENTION

In accordance with an embodiment of the present invention, a linear position sensor is comprised of a magnetic field generator such as an electro magnet for generating an alternating magnetic field, a Wiegand wire that extends along and is adjacent to a possible linear path of travel of the magnetic field, and at least one pickup coil wound on a portion of the Wiegand wire that is responsive to changes in the magnetic state of a segment of the Wiegand wire. A position of the magnetic field generator along the linear path is ascertained from the response of the pickup coil(s).

As one aspect of the present invention, first and second pickup coils are wound on different portions of the Wiegand wire and the position of the magnetic field generator is ascertained from the response of the first pickup coil and the response of the second pickup coil.

As another aspect of the present invention, a change of magnetic state in a segment of Wiegand wire produces a pulse on a pickup coil that is wound on that segment and the position of the magnetic field generator is ascertained from the pulses produced.

As a further aspect of the present invention, the first and second pickup coils partially overlap one another on the Wiegand wire and are both responsive to a change of magnetic state of any segment of Wiegand wire located within the overlapping portion of the Wiegand wire.

As an additional aspect of the present invention, a non-magnetic tubing is provided that extends along and is adjacent to the possible linear path of travel, the Wiegand wire is positioned within and extends along the interior of the non-magnetic tubing, and the pickup coils are wound on portions of the non-magnetic tubing.

BRIEF DESCRIPTION OF THE DRAWINGS

The following detailed description, given by way of example and not intended to limit the present invention solely thereto, will best be appreciated in conjunction with the accompanying drawings, wherein like reference numerals denote like elements and parts, in which:

Fig. 1 is a schematic illustration of the Wiegand effect linear position sensor of the present invention;

Fig. 2 is a circuit diagram of an exemplary electro magnet drive circuit that may be used to drive the electro magnet of the present invention; and

Fig. 3 is a circuit diagram of an exemplary coil pickup circuit.

DETAILED DESCRIPTION OF CERTAIN PREFERRED EMBODIMENTS

The linear position sensor of the present invention employs what has come to be known as the Wiegand Effect that is described in U.S. Patent 3,820,090. As discussed below, the present invention utilizes an electro magnet movable along a linear path in combination with a Wiegand wire and a number of pickup coils wound thereon. As is known, the Wiegand wire is a ferro magnetic wire having core and shell portions with divergent magnetic properties. The currently preferred type of Wiegand wire is disclosed in U.S. Patent No. 4,247,601, issued on January 27, 1981, and which is incorporated herein by reference. The Wiegand wire generally is used in combination with a read head which provides an output pulse from a switch in state of the Wiegand wire. Examples of such a read head are described in U.S. Patent Nos. 4,263,523, 4,593,209 and 4,736,122. Another read head is disclosed in co-pending patent application serial no. 09/015,873, filed January 29, 1998, which is incorporated herein by reference.

Referring now to the drawings, Fig. 1 is a schematic illustration of the Wiegand effect linear position sensor of the present invention. As shown, the sensor includes a non-magnetic

tubing 10 and within tubing 10 extends a Wiegand wire 12. A number of pickup coils 14a, 14b and 14c are wound on tubing 10 at different locations thereof. As will be discussed, the length along tubing 10 on which a respective pickup coil is wound represents a respective location that is being sensed. The sensor further includes a coil pickup circuit to which the pickup coils 14a, 14b and 14c are supplied and in response thereto provides a control signal that identifies the sensed position. In the given example, three pickup coils are wound on tubing 10 and thus there are three different linear positions that are identified. Of course, any number of pickup coils may be wound on tubing 10. The ends of the pickup coils may overlap each other so as to provide a smooth transition from one linear position to the next.

The sensor further includes an electro magnet 20 that operates to "drive" a segment of Wiegand wire 12. Electro magnet 20 includes a magnet 22 along with drive coil 24. In accordance with the present invention, electro magnet 20 is driven by, for example, the circuit shown in Fig. 2 to provide an alternating magnetic field across its face 22a. Since the operation of the circuit of Fig. 2 is easily understood to one of ordinary skill in the art, no further description is provided herein. It also is understood that other known drive circuits may be used by the present invention.

In accordance with the present invention, the position of electro magnet 20 along tubing 10 represents the position that is sensed by the present invention. In the example given above, the position of a vehicle seat is utilized in a vehicle occupant restraint system. By placing electro magnet 20 within the vehicle seat and by fixing non-magnetic tubing 10 (with Wiegand wire 12 therein) to an appropriate location that remains fixed with respect to, for example, the floor of the vehicle and tubing 10 spans alongside the possible path of travel of electro magnet 20, the linear position sensor of the present invention is operable to identify the location at which the vehicle seat is placed. In addition, location precision of the vehicle seat may be increased by increasing the number of pickup coils wound on tubing 10 and

decreasing the length of each segment of tubing 10 on which each respective pickup coil is wound.

In operation, electro magnet 20 produces an external magnetic field that cycles (e.g., at 60 Hz) between polarities. That is, electro magnet 20 has reversing magnetic poles. At the full positive field, both the shell and core of a segment of Wiegand wire 12 that is immediately adjacent to electro magnet 20 and thus within the magnetic field are magnetized in the positive direction. This is considered to be the positive confluent state of the Wiegand wire segment. As the external field decreases from a positive field to a relatively small negative field, the core of the Wiegand wire segment switches its direction of magnetization from positive to negative, which is considered to be the reverse state. The switching of the segment of the Wiegand wire from the confluent state to the reverse state results in a significant output pulse in that particular pickup coil (e.g., pickup coil 14b) wound around the segment of Wiegand wire switching states.

As the external field produced by electro magnet 20 continues to increase in the negative direction (i.e., as the negative field increases) and approaches the negative peak, a point is reached where the direction of magnetization of the shell of the Wiegand wire segment switches from positive to negative, wherein the core and shell are now in a negative confluent state. This transition results in a relatively small output pulse in the adjacent pickup coil, but this small output pulse is not necessary to carry out the present invention and thus is not utilized.

The magnetic field produced by electro magnet 20 continues to increase (in the negative direction) until the maximum negative peak is reached and then decreases until a relatively small positive field is reached, at which point the core of the Wiegand wire segment switches its direction of magnetization from negative to positive. The core and shell of the Wiegand wire segment are now in the reverse state, and the switching of the Wiegand wire

segment from the negative confluent state to the reverse state results in another significant output pulse, but opposite in polarity from the previous significant pulse, in the adjacent pickup coil.

The external field continues to increase and just prior to reaching its positive peak the direction of magnetization of the shell of the Wiegand wire segment switches from negative to positive which results in another relatively small output pulse (but opposite in polarity to the previous small output pulse) in the adjacent pickup coil. Like before, this small output pulse is not utilized. At this point, the core and shell are back in the positive confluent state. The field continues to increase until the positive peak is reached at which point the cycle described herein repeats itself.

As previously mentioned, the three pickup coils 14a, 14b and 14c, shown in Fig. 1, are supplied to an appropriate coil pickup circuit that generates an output that identifies the pickup coil on which the above-described pulses are produced which in turn identifies the position of electro magnet 20 along tubing 10. The identified position of electro magnet 20 identifies the position of, for example, the vehicle seat. Fig. 3 is an exemplary coil pickup circuit that identifies the pickup coil being activated wherein each light-emitting diode (LED D1, D2 and D3) represents a respective pickup coil 14a, 14b and 14c. When electro magnet 20 is adjacent to one of the pickup coils, the corresponding LED will light and remain on until electro magnet 20 moves to a position that is not adjacent to that pickup coil. Since one of ordinary skill in the art would readily understand the operation of the circuit of Fig. 3, further description thereof is omitted herein except where necessary for an understanding of the present invention. Of course, the circuit of Fig. 3 merely represents an exemplary coil pickup circuit that may be used by the present invention. Other coil pickup circuits may generate and output a data signal that identifies the sensed position.

In a preferred embodiment of the present invention, the ends of adjacent pickup coils

overlap one another, which results in two advantageous features of the present invention. First, there is a smooth transition from one linear position to the next, as previously mentioned. Second, each overlapping set of pickup coils results in an additional position that may be identified by the linear position sensor of the present invention, the additional position being that portion along tubing 10 on which both of the adjacent pickup coils are wound. When electro magnet 20 is located adjacent to a portion of tubing 10 on which two pickup coils are wound, pulses are produced on both pickup coils which may be easily identified by a coil pickup circuit to represent a unique position. If, for example, three pickup coils 14a, 14b and 14c are wound on tubing 10 in the manner shown in Fig. 1, and pickup coils 14a and 14b partially overlap one another and pickup coils 14b and 14c also partially overlap one another, then the linear position sensor is operable to sense electro magnet 10 in one of five different linear positions along the linear path.

As discussed above, the linear position sensor of the present invention senses the position of electro magnet 20, and such position may change while that position is be sensed. During such movement and position sensing, the core and shell of different segments of Wiegand wire 12 change state in the manner discussed above. Since the rate of movement of electro magnet 20 generally is substantially less than its magnetic field cycle rate (e.g., 60 Hz), such motion of the electro magnet has little to no bearing on position sensing. If the rate of motion is expected to be relatively fast, then the magnetic field cycle rate may be increased if necessary.

In accordance with the present invention, and as will be understood, the disclosed linear position sensor advantageously does not have a so-called "assumed" condition. In many types of devices, including positional sensors and other devices, a generated output carries with it one or more pieces of information wherein a null or default output likewise represents a value. For example, a positional sensor may provide a positive output, a zero

output or a negative output, each representing a respectively different position. A fault in this type of sensor likely would result in a null or zero output which would erroneously be identified to represent a position. Faults resulting in a fixed positive output (or negative output) also are possible. The present invention, on the other hand, has no such assumed or null condition. Instead, a repeating pulse must be present on at least one of the pickup coils for the linear position sensor to be operating properly. A fault in any of the components of the linear position sensor of the present invention would result in no such pulsing and thus would be detected by the attached coil pickup circuit.

While the present invention has been particularly shown and described in conjunction with a preferred embodiment thereof, it will be readily appreciated by those of ordinary skill in the art that various changes may be made without departing from the spirit and scope of the invention. For example, although the present invention has been described as including three pickup coils, any number of coils may be used and the distance along tubing 10 covered by each coil may be the same or may be different, such generally being determined from the specific requirements of the application.

As another example, although the disclosed embodiment includes only a single electro magnet that travels along a linear path adjacent to a single non-magnetic tubing, a multiple number of electro magnets and/or a multiple number of non-magnetic tubings (with Wiegand wire therein and pickup coils wound thereon) may be utilized.

As a further example, although the non-magnetic tubing shown in Fig. 1 is relatively straight thus representing a straight path of travel of the electro magnet, the path of travel and thus the shape of the non-magnetic tubing may be curved or have any other desired shape.

As an additional example, although the disclosed embodiment suggests that the electro magnet moves along a stationary path that is adjacent to the non-magnetic tubing, the linear position sensor of the present invention detects the position of the electro magnet along

the linear path regardless of whether or not the linear path (i.e., the non-magnetic tubing) is stationary. Therefore, the present invention may be easily utilized in the situation where the electro magnet is stationary and the non-magnetic tubing is movable. Still further, both the electro magnet and the non-magnetic tubing may be movable.

Therefore, it is intended that the appended claims be interpreted as including the embodiments described herein, the alternatives mentioned above, and all equivalents thereto.

WHAT IS CLAIMED IS:

1. A linear position sensor, comprising:

field generating means for generating an alternating magnetic field;

a Wiegand wire extending along and being adjacent to a possible linear path of travel of said field generating means, a segment of said Wiegand wire located within said magnetic field generated by said field generating means changing a magnetic state thereof in response to said magnetic field; and

at least one pickup coil wound on a portion of said Wiegand wire and being responsive to a change of magnetic state of any segment of Wiegand wire within said portion of said Wiegand wire.

2. The linear position sensor of claim 1, wherein said at least one pickup coil includes a first pickup coil wound on a first portion of said Wiegand wire and a second pickup coil wound on a second portion of said Wiegand wire, said first pickup coil being responsive to a change of magnetic state of any segment of Wiegand wire located within said first portion of said Wiegand wire, and said second pickup coil being responsive to a change of magnetic state of any segment of Wiegand wire located within said second portion of said Wiegand wire.

3. The linear position sensor of claim 2, further comprising position identification means for receiving said first pickup coil and said second pickup coil and for identifying a position of said field generating means in response thereto.

4. The linear position sensor of claim 2, wherein a pulse is produced on said first pickup coil in response to a change of magnetic state of a segment of Wiegand wire within

said first portion of said Wiegand wire, and a pulse is produced on said second pickup coil in response to a change of magnetic state of a segment of Wiegand wire within said second portion of said Wiegand wire.

5. The linear position sensor of claim 4, further comprising position identification means for receiving said first pickup coil and said second pickup coil, and for identifying a position of said field generating means as a function of the occurrence or non-occurrence of pulses on said first pickup coil and said second pickup coil.

6. The linear position sensor of claim 5, wherein said position identification means identifies said position of said field generating means as a function of the occurrence or non-occurrence of repeating pulses on said first pickup coil and said second pickup coil.

7. The linear position sensor of claim 2, wherein said first pickup coil and said second pickup coil are wound on different portions of said Wiegand wire.

8. The linear position sensor of claim 2, wherein said first and second pickup coils partially overlap one another such that said first and second portions of said Wiegand wire partially overlap one another, and said first and second pickup coils both being responsive to a change of magnetic state of any segment of Wiegand wire located within said overlapping portion of said Wiegand wire.

9. The linear position sensor of claim 8, further comprising position identification means for receiving said first pickup coil and said second pickup coil and for identifying a position of said field generating means as a first position when said first pickup coil is

responsive to a change of magnetic state of a segment of Wiegand wire, for identifying said position of said field generating means as a second position when said second pickup coil is responsive to a change of magnetic state of a segment of Wiegand wire, and for identifying said position of said field generating means as a third position when both said first and second pickup coils are responsive to a change of magnetic state of a segment of Wiegand wire.

10. The linear position sensor of claim 1, further comprising a non-magnetic tubing extending along and being adjacent to said possible linear path of travel of said field generating means; and wherein said Wiegand wire is positioned within and extends along an interior of said non-magnetic tubing, and said at least one pickup coil is wound on a portion of said non-magnetic tubing.

11. The linear position sensor of claim 1, wherein a position of said field generating means is fixed relative to a reference point, and said Wiegand wire is movable relative to said reference point; and said linear position sensor further includes position identification means for identifying a position of said Wiegand wire relative to said reference point in response to signals on said at least one pickup coil.

12. A method of sensing the linear position of an object, comprising the steps of:

generating an alternating magnetic field at a movable position to be sensed;

placing a Wiegand wire adjacent to and along a possible path of travel of said movable position to be sensed;

producing a response to a change of magnetic state of a segment of said Wiegand wire; and

identifying the position in accordance with the response produced.

13. The method of claim 12, wherein the step of producing a response is carried out by winding at least one pickup coil around a portion of said Wiegand wire, and generating a pulse in said at least one pickup coil in response to a change of magnetic state of any segment of said Wiegand wire located within said portion of said Wiegand wire.

14. The method of claim 12, wherein the step of producing a response is carried out by winding a first pickup coil around a first portion of said Wiegand wire, and winding a second pickup coil around a second portion of said Wiegand wire, the first and second pickup coils being responsive to changes in magnetic state of segments of Wiegand wire located within the first and second portions, respectively.

15. The method of claim 14, wherein the step of identifying the position is carried out in response to the respective response of each of said first and second pickup coils.

16. The method of claim 14, wherein the first pickup coil and the second pickup coil are wound on different portions of said Wiegand wire.

17. The method of claim 14, wherein the first and second pickup coils partially overlap one another such that said first and second portions of said Wiegand wire partially overlap one another, and said identifying step is carried out by identifying the position as a first position when said first pickup coil is responsive to a change of magnetic state of a segment of Wiegand wire, by identifying the position as a second position when said second pickup coil is responsive to a change of magnetic state of a segment of Wiegand wire, and by identifying the position as a third position when both said first and second pickup coils are responsive to a change of magnetic state of a segment of Wiegand wire.

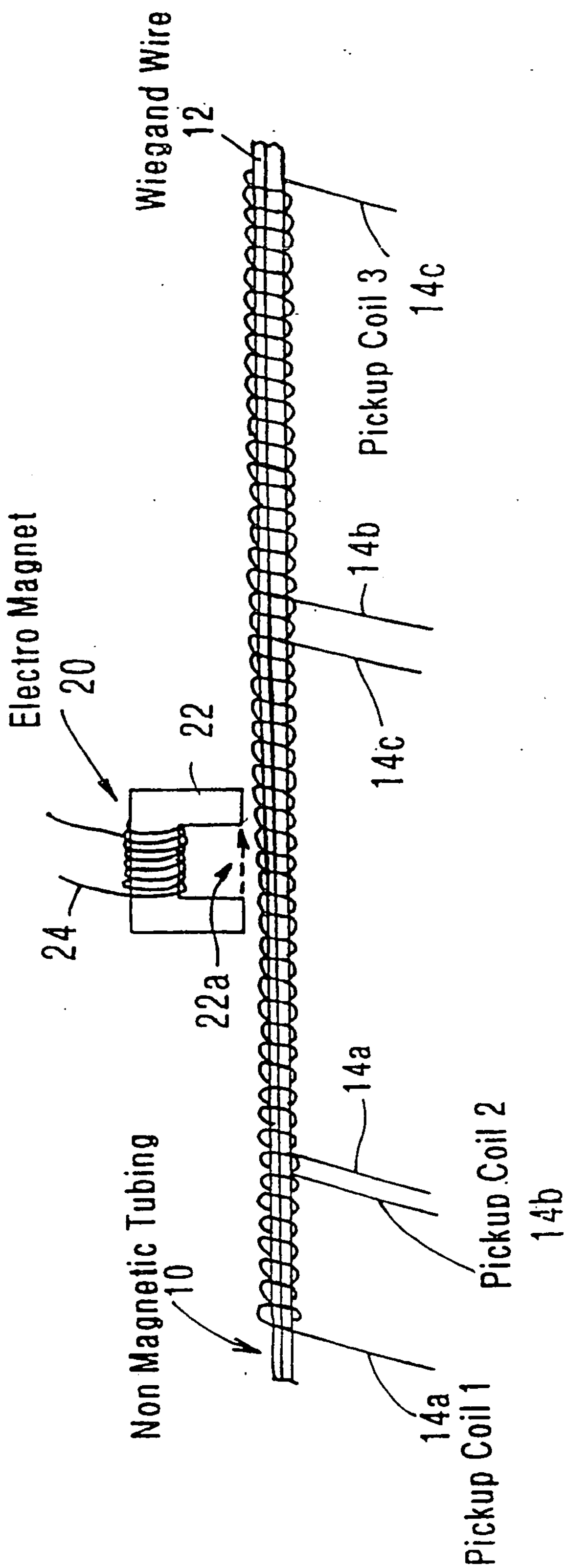
Wiegand Wire
12
Pickup Coil 3
14c
14b
14c
Electro Magnet
20
22
24
22a
14a
Pickup Coil 2
14b
Non Magnetic Tubing
10
14a
Pickup Coil 1

FIG.1

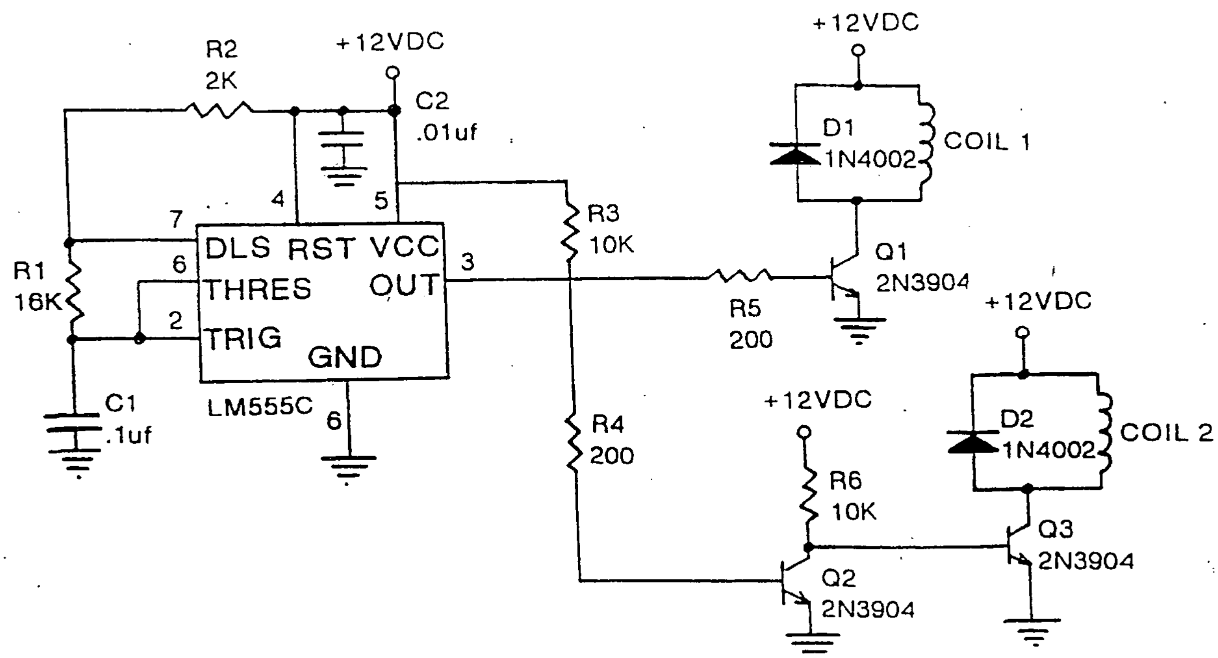
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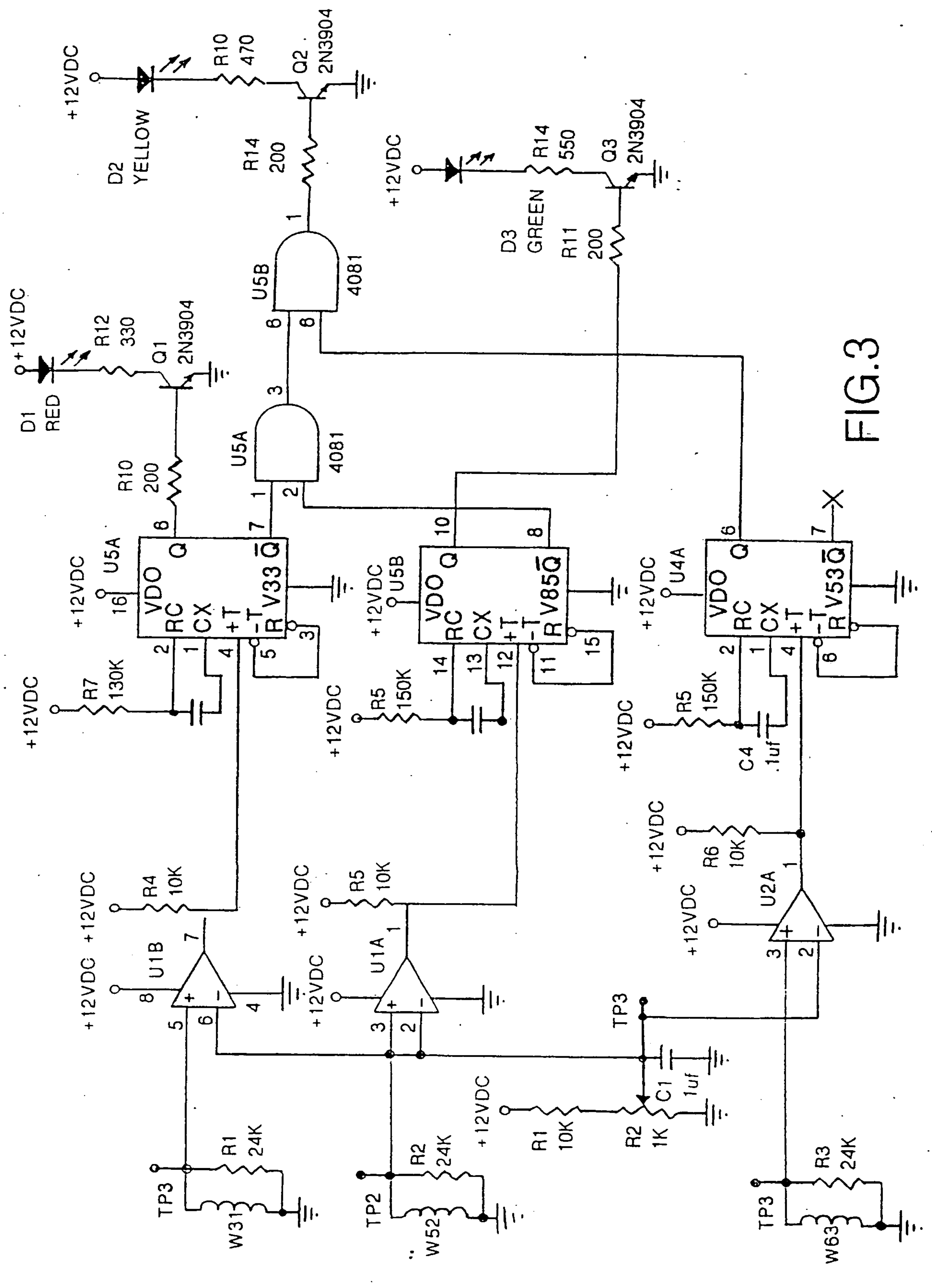
FIG.2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4081
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R5
150K
C4
.1uf
R6
10K
R4
10K
R5
10K
U1B
U1A
U2A
TP3
C1
1uf
R1
10K
R2
1K
R1
24K
W31
TP2
R2
24K
W52
R3
24K
W63

FIG.3

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 99/08144

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G01D5/14

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G01D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GEVATTER H -J ET AL: "WIEGAND-SENSOREN FUER WEG- UND GESCHWINDIGKEITSMESSUNGEN. WIEGAND EFFECT POSITION AND SPEED SENSORS" TECHNISCHES MESSEN TM, vol. 51, no. 4, 1 April 1984 (1984-04-01), pages 123-129, XP002027038 ISSN: 0171-8096 page 128, left-hand column -----	1,12

☐ Further documents are listed in the continuation of box C.

☐ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
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Date of the actual completion of the international search	Date of mailing of the international search report
9 July 1999	15/07/1999

Name and mailing address of the ISA	Authorized officer
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